Renewability and Usability of the Groundwater Resources in Western ElMinia, Upper Egypt.

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Abstract

The estimation of groundwater renewability and usability is a crucial task in groundwater research and management. In this study, sixty seven groundwater samples were collected from the Eocene groundwater aquifer of southwestern ElMinia, Egypt; these were subjected to both hydrochemical (major ions and trace elements) and isotopic (^{18}O, D, ^{3}H and ^{14}C) analysis to determine the groundwater renewability and usability which embed the qualitative and quantitative themes of the resource.

It was revealed that the groundwater under study gets two sources recharge, from both present day Nile water system and upward leakage of deep seated Paleowater through faults, joints and factures. The Paleowater contribution in the samples of mixed recharge varies from 1.7 % to 73% (it equals < 30%, from 30% to 50% and from 50% to 70 % for about 13%, 75% and 12% of the mixed recharge samples, respectively). The Paleowater contribution increases westward and solely exists at about 40-50 km away from Nile flood plain, with isotopic footprints (^{18}O, ^{3}H, ^{14}C age equal -10%0, 0.0 TU, 10100ybp).

The Canadian Environmental Quality Guidelines index (CEQGI) has been used to evaluate the usability of groundwater under study for drinking purposes, based on major ions and trace elements content. About 60% of the collected groundwater samples are categorized as poor (almost always threatened) and 40% are Marginal (frequently threatened) when used for human drinking. The possible health risks posed to the human health have been evaluated for non-carcinogenic and carcinogenic effects of heavy metal, revealing that both risks are greater than the allowable limit.

***Keywords:** Renewability, Isotope Hydrology, Water Quality, Health Hazard.*

I. Introduction

The steadily growing population with the shortage in water resource and agricultural deficit in the Nile Valley and flood plain, let the government strategically plans to extend the agricultural, industrial and civil development to desert areas. This implies an increasing demand for sustainable groundwater resource to cope with the excessive needs. The occurrence of groundwater outside the Nile valley in either fissured carbonate rocks or Paleowater aquifers requires comprehensive understanding of the groundwater renewability and recharge activity to determine the reliability and to manage the usability. A quantitative balance should be kept in the hydrogeological system to satisfy the needs of humans and ecosystems for the present and future. The active recharge and renewability of the groundwater resources are highly important with proper management, to optimize the conditions of groundwater utilization. It is an urgent task to explore the activity of recharge and renewability of groundwater for keeping hydrogeological balance and sustainable development. The groundwater quality is as much important as quantity; it constrains the usability and determines the hazards or safety as well as protectability. Groundwater quality is foundation for pollution; hence, the use of contaminated groundwater for consumption might represent a hazard for human health. The quality of irrigation water has a profound effect on productivity of crops and their growth, and also effects the soil properties (porosity and permeability).

The use of isotopic techniques, integrated with traditional hydrologic and hydrogeochemical tools, provides a rapid and accurate understanding of the groundwater systems and characterizing its regime. Applications of stable isotope ratios of hydrogen and oxygen (D and ^{18}O) in groundwater are based primarily upon isotopic variations in precipitation and the subsequent alterations in the hydrogeological systems. The average meteorological parameters and the stable isotopic composition of rainwater in correlation with groundwater, define the origin and movement of subsurface waters and interconnection between them. The different sources of recharges (rain, rivers, seas, and lakes ….etc.) have specific isotopic compositions that label them and fingerprint the atmospheric and hydrologic conditions under which they are formed. Applications of the radioactive isotopes of hydrogen and carbon (^{3}H and ^{14}C) in groundwater are based on the constant

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radioactive decay and continuous loss of activity gained from atmosphere at time of contact. This helps to know the age and residence time of groundwater since it losses connection with atmosphere. The short half-life of ^{3}H provides valuable information on recent recharge whereas the long half-life of ^{14}C dates slow-moving groundwater. The radioactive and stable isotopes data, when used with hydrogeological data, enable to decide about groundwater recharge sources, renewability, potentiality and continuity.

Recently, water quality index (WQI) is used in the assessment of the groundwater suitability for different purposes throughout the world and serve as an effective tool for appraising the groundwater quality. It is defined as a technique of rating that provides the composite influence of individual water quality parameter on the overall quality of water for drinking as well as irrigation purposes; it transforms the entire groundwater quality data for each well into a single number called index **(Sadat-Noori et al. 2014, El-Shahat etal 2015 and Hagagg etal 2020)**.The industrial and domestic wastewater may induce a variety of heavy metal pollutants that are difficult to be degraded in the environment **(He and Li 2020)**, such as Cr, Sr, Ni, Cd, Cu, and Fe, that might cause certain harm to the human health. They can interact with proteins and deactivate it or cause human poisoning. Total concentrations of heavy metal contaminants in groundwater are often used for human health risk assessments.

Aim of the work

The present work is devoted to determine the recharge sources, renewability and usability of the groundwater resources in western south ElMinia area, Upper Egypt. It   functions isotopic finger print with hydrochemical and hydrogeological attributes to determine recharge sources, renewability (Paleowater / Recent water ratio), quality hazards and health risks of groundwater for drinking purposes. This information is important for groundwater potentiality and reliability and considers the quantitative and qualitative bounds for development prospects.

The Study area

The study area of southwest ElMinia, mid Upper Egypt, is one of the promising areas for future development plans in Egypt. It lies in the western reaches of Nile valley, bounded by latitudes 27 30° and 28 20° and longitudes 30 20° and 30 50°, Fig. (1). It is characterized by an arid to semiarid climate, limited rainfall< 10 ml/y and high surface evaporation about 8 mm/d. Its surface elevation and slope increase from east to west.
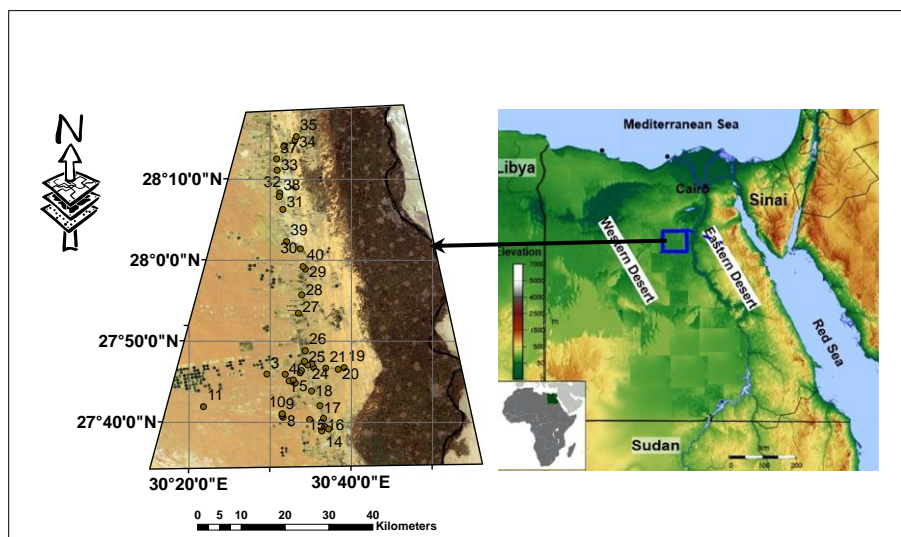

Fig.(1): Location map of the study area with collected samples.

Three geomorphologic units appear in the study area, from east to west (young alluvial plain, old alluvial plain and plateau). The young alluvial plain bounds the Nile River and is filled with Holocene silt and clay, it is followed westward by old alluvial plain unit which is covered by Pleistocene sands and gravels and followed westward by the lower Eocene Plateau

The study area is characterized by a lithostratigraphic succession dominated by Eocene limestone rock units and post-Eocene ones that include: (1) Oligocene sands and gravels which are exposed in the west and northwestern part of the study area, (2) Pliocene dark clays and undifferentiated sands, (3) Pleistocene alluvial deposits (sand, gravel with clay lenses), (4) Holocene Nile silt and clay **(Said, 1990)**, Fig. (2) illustrate the geological map of the study area and its vicinity.

Hydrogeologically, two main aquifers are encountered in the area under study and surroundings namely the Quaternary (alluvium) aquifer and the Eocene limestone aquifer. In addition to these aquifers, the deep Nubian sandstone aquifer which underlain the whole western desert, it contains Paleowater of no recent recharge, its high pressure in a presence of joints and fractures gets it pass to the upper aquifers, Fig. (2) shows a general hydrogeological cross section extending from the flood plain, westward till the plateau.

The Quaternary aquifer is unconfined to semi confined, formed of Nile alluvium (graded sand and gravel with intercalations of clay lenses) resting directly on the Pliocene clay and the fissured Eocene limestone. It extends north / south parallel to the Nile River with thickness increasing eastward (about 5m to 100m). The Eocene limestone aquifer which is the subject of this work is mainly represented by Samalut Formation which is made up of hard, white and highly fossiliferous limestone with shale and marl intercalations. It is unconfined aquifer, underlies the alluvium aquifer and overlies the Nubian sandstone aquifer (**Tantawy, 1992**) and dominates in the western sides of flood plain and desert fringes. This limestone aquifer contains fissures, fractures, and joints which represent the conduits of the groundwater system.
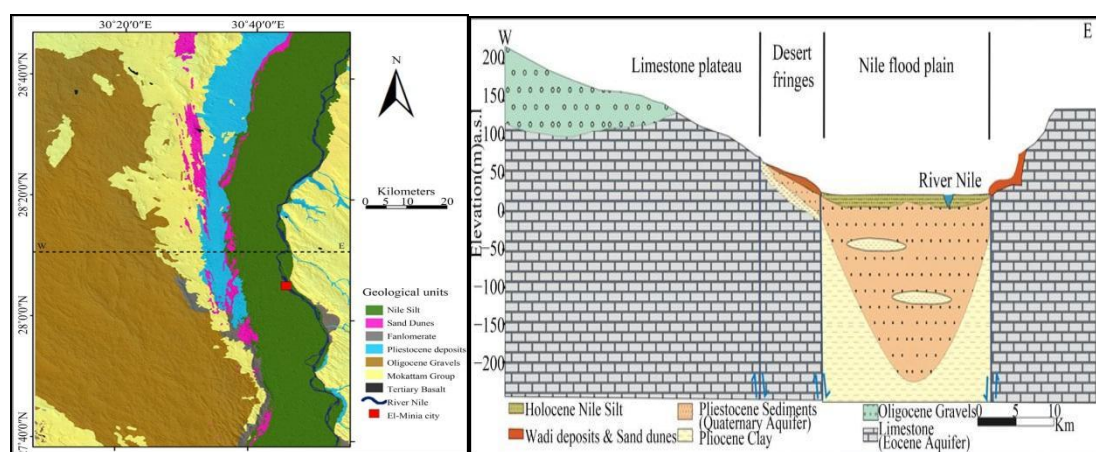

Fig.(2): Geological map of the study area (at the right) and Hydrogeological section (at the left), (Abdel Moneim etal, 2016).

II. Materials and Methods

Fifty groundwater samples were collected from the Eocene aquifer in the study area, Fig. (1)**,** these were subjected to insitue physical measurements including (EC), (pH), temperature and TDS using portable meters. The major ions (Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, HCO_3^-, SO_4^{2-}) and isotopic content (^{18}O, D, ^3H) and six samples for ^{14}C have been analyzed for the water samples in Central Laboratory of Isotope Hydrology at Nuclear and Radiological Regulatory Authority.

The major ions analyses follow the methods described in (**APHA, 1995**). Total hardness (TH) was measured as $CaCO_3$, the Ca^{2+} was analyzed using standard EDTA, Mg^{2+} was calculated by taking the differential value between TH and Ca^{2+} concentrations. Na^+ and K^+ were measured using a flame photometer. Total alkalinity and $CaCO_3$, CO_3^{2-}, and HCO_3^- were measured by titration with HCl. Cl^- was determined by standard $Ag(NO_3)_2$ titration. SO_4^{2-} and NO_3^- were analyzed using a spectrophotometer. All the parameters are expressed in milligrams per liter. The trace elements (Al, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Si, Sr, Ti, V, and Zn) were measured by ICP (Inductively Coupled Plasma) at Desert Research Centre DRC.

The stable isotopes measurements have been conducted for Oxygen -18, Deuterium according to the standard methods using Laser spectroscopy Piccaro (Model 2120i). Both ^{18}O and D isotopic compositions are reported in permil (‰) deviation from isotopic standard reference material using the conventional **δ** notation, where:

$$\delta\ ‰ = ((R\ sample\ /\ R\ standard\ ) -1) \times 1000$$

R sample and R standard are the measured isotopic ratios ($^{18}O/^{16}O$) and ($^2H/^1H$) of sample and standard reference material. The reference material is Vienna Standard Mean Ocean Water (VSMOW). All results are evaluated, corrected and reported against VSMOW. The typical standard deviation for oxygen is ±0.1‰ and ± 0.6‰ for hydrogen.

The Tritium content of selected samples have been determined using Liquid Scientillation Counter Quantulus 1200 after electrolytic enrichments, The results are reported in a Tritium Unit (TU) where 1 TU equal 10^{-18} ^1H. The carbon-14 age was determined for selected samples using CO_2 absorption method after field

precipitation of inorganic carbonaceous specious in form of Ba CO_3 , the ^{14}C ages were determined in year before present (ybp) unit, based on the sample content as percentage of modern carbon (pmc).

The results data from both hydrochemical and isotopic analysis have been treated, analyzed, processed using standard reference methods, to determine the groundwater rechargability, renewability and usability in the study area.

III. Results and Discussion

3.1 Recharge Sources and Renewability

The sources of groundwater recharge in Egypt (rain water, River Nile prior to high dam construction (Old Nile), Present day River Nile, Paleowater of western desert (Nubian Sandstone Aquifer),……etc) have highly differentiated and distinguishable isotopic content (**Table 1**), this helps to fingerprint the contribution of different recharge sources in a given aquifers.

Table (1): Average isotopic content of possible groundwater recharge sources in the study area.

Recharge Source	$\delta^{18}O(‰)$	$\delta D(‰)$
Old Nile (**Nile water** that was flooding the area before construction of High Dam and still preserved in less actively recharged zones), (Awad, 1997).	-0.6	4.3
Paleowater of western desert (Nubian Sandstone), (Awad, 1997)	-10	-80
Recent Nile (Present study)	3.1	28.3

The isotopic values of oxygen -18 and deuterium of the sampled wells (with one surface water samples collected from Bahr Yousef canal) are statistically summarized in shown in Tables (2A, 2B and 2C), the ranges, means and standard deviations are shown in those tables.

Table (2A): Statistical analyses of the chemical results in the study area.

Item	pH	EC (µS/cm)	TDS (mg/l)	Na^+	K^+	Mg^{2+}	Ca^{2+}	Cl^-	SO_4^{2-}	HCO_3^-
Mean	8.18	1577.92	1166.41	219.87	9.18	51.21	38.85	329.77	132.47	227.02
Minimum	6.69	623.00	467.00	57.50	3.95	24.48	10.01	71.00	48.00	61.00
Maximum	9.20	6880.00	5160.00	1219.00	19.75	122.40	120.12	1704.00	768.00	488.00
Standard Deviation	0.49	1296.34	980.06	234.87	4.57	23.20	29.26	342.28	154.29	61.36
Sample Variance	0.24	1680489.35	960521.75	2398.39	0.53	43.96	42.77	3300.12	495.95	61.72
Kurtosis	2.41	8.04	7.90	216.47	38.99	52.24	28.56	277.54	447.36	576.64
Skewness	-0.74	2.72	2.70	67.54	45.00	26.18	30.16	94.93	145.86	100.50

Table (2B): Statistical analyses of the chemical results in the study area.

Item	*Al*	*Cd*	*Co*	*Cr*	*Fe*	*Ni*	*Pb*	*Sr*
Mean	0.08	0.01	0.02	0.03	0.18	0.05	0.14	0.70
Minimum	0.01	0.00	0.00	0.01	0.02	0.00	0.01	0.04
Maximum	0.30	0.03	0.12	0.29	0.80	0.19	0.57	2.97
Standard Deviation	0.07	0.01	0.03	0.06	0.19	0.05	0.16	0.70
Sample Variance	0.01	0.00	0.00	0.00	0.04	0.00	0.02	0.49
Kurtosis	1.58	0.92	6.36	10.68	2.63	0.77	0.55	2.88
Skewness	1.28	1.27	2.37	3.35	1.61	0.91	1.17	1.78

Table (C): Statistical analyses of the isotopic results in the study area.

Item	$\delta^{18}O$ (‰)	δD (‰)	^3H (TU)	^{14}C (ybp)
Mean	-2.11	-12.36	2.17	5022
Minimum	-6.51	-49.97	0	4735
Maximum	-0.44	-1.2	2.86	5649
Standard Deviation	1.03	8.68	0.79	340.5
Sample Variance	1.06	75.3	2	115965.2
Kurtosis	8.12	8.38	-1.84	2.3
Skewness	-2.14	-2.19	-0.78	1.63

The values of oxygen18 and deuterium content of the study ground water samples vary in the range from -6.5 ‰ to -0.44 ‰ and -49.97 ‰ to -1.2 ‰, respectively and that of surface water (Bahr Yousef canal) equal 3.98 ‰ and 29.85‰; the indicated isotopic content is combatable with the range of isotopic variation of the two recharge sources end members in Egypt (i.e Nile River and irrigation canal in the +ve end and Paleowater of western desert at the –ve end).

The conventional $\delta^{18}O$ vs δD diagram has been constructed (Fig. 3) and the points of major recharge sources are plotted for comparison. The isotopic values of the samples points are highly co-relatable to each other with a linear pattern :($\delta D‰ = 8.39 \delta^{18}O‰ + 6.11$, $R^2 = 0.98$), completely fits with the mixing line between Nile water and Paleowater, this pattern indicates that the major sources of recharge of the sampled groundwater wells are Nile water and Paleowater that leaks upward from deep Nubian Sandstone aquifer through faults and fractures. The slope (close to 8) of the linear fitness of the samples indicates that recharge takes place directly in the two interconnected aquifers (Pleistocene and Eocene), with limited chance for surface evaporation. The point of Old Nile water lies very close to the mixing line; this could reflect a contribution of residuals from Nile water floods that occurred prior to High Dam construction, still remaining in the Pleistocene aquifer in contact
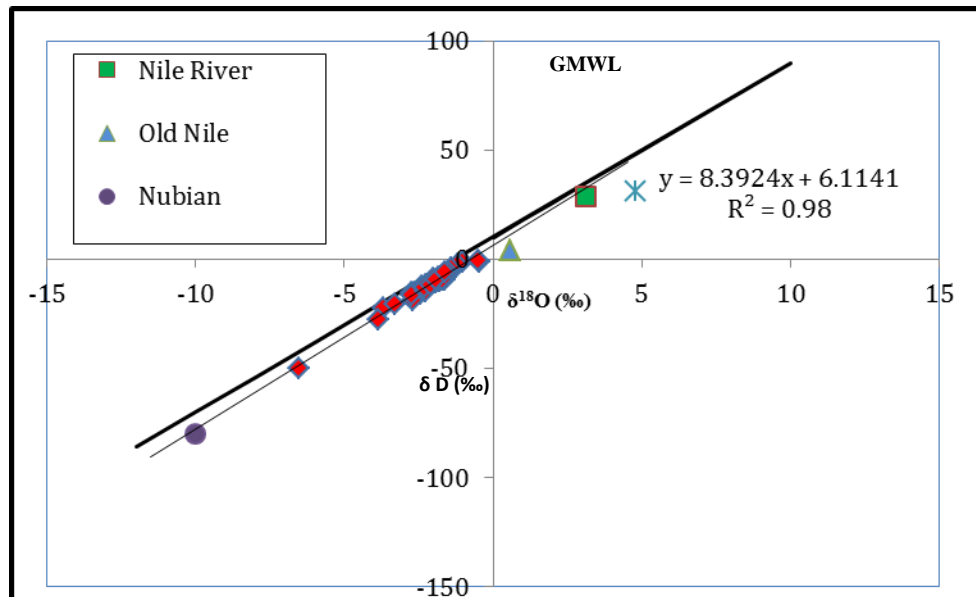
Fig. (3): Conventional $\delta^{18}O$ / δD Relationship

The areal distribution of $\delta^{18}O$, Fig. (4) shows a general pattern of depletion from East to west in the direction from Nile flood plain – desert fringes to the limestone table land. This direction complies with the decrease of Quaternary aquifer thickness (which gets its major recharge from Nile River and irrigation canal) and increase of the interconnected Eocene limestone aquifer (which gets its major recharge, through fractures, as upward leakage from deep fossil water aquifer). The fossil water recharges increases westward and become dominant without traces of present day recharge at about 50km away from Rive flood plain.
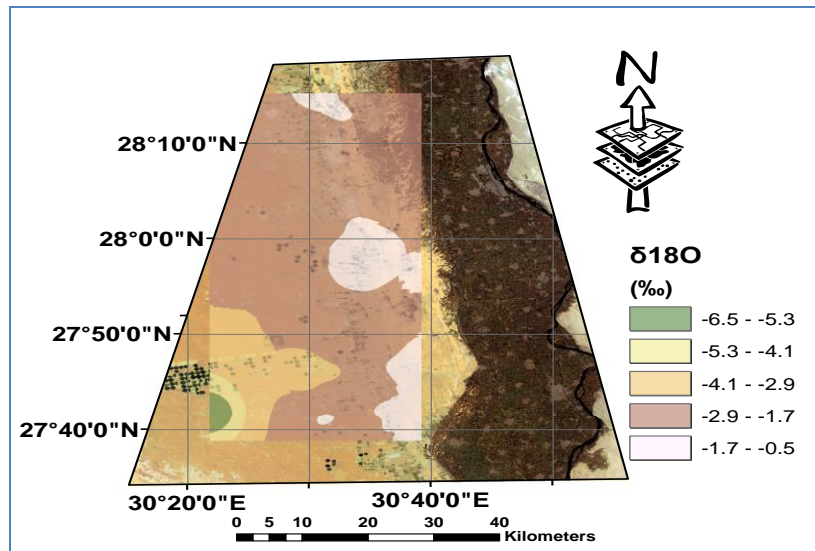
Fig.(4): Isotopic pattern of δ^{18}O for the studied samples.

The analyzed groundwater samples have tritium values in the range from 0.0 TU to 2.86 TU, Table (2C). The tritium content of River Nile recharge (represented in this work by Bahar Yousef canal) equals 5.0 TU while Paleowater contains no tritium. The appearance of tritium in the studied groundwater samples indicates the occurrence of recent and/or sub-recent recharge in the aquifer storage and refers to its renewability and potentiality, the decrease of its values compared to that of Nile water reflects either different residence times of the recent recharge and /or mixing with Paleowater of no tritium.

The relation of TDS with δ^{18}O and Tritium (Figs.5A, 5B) shows a general trend of increasing salinity with decreasing δ^{18}O and tritium. This trend could express the salinity development, due to mixing between isotopically enriched present day fresh Nile water and the isotopically depleted higher salinity fossil water. The dispersion of the points and the tendency to have more than one parallel patterns may be related to the fact that δ^{18}O is only affected by mixing in this pattern while TDS is affected by mixing as well as rock /water interaction processes as leaching , dissolution , precipitation, ...etc.

The δ^{18}O vs Tritium Fig. (5C) shows a general trend of increasing tritium content with δ^{18}O enrichment, pointing out to the mixing between Nile Water and Paleowater in the groundwater recharge, the dispersion of the points in the relation may be due to the fact that tritium content is not only affected by mixing but also with residence and transit time (two patterns may be noticed in the relation).
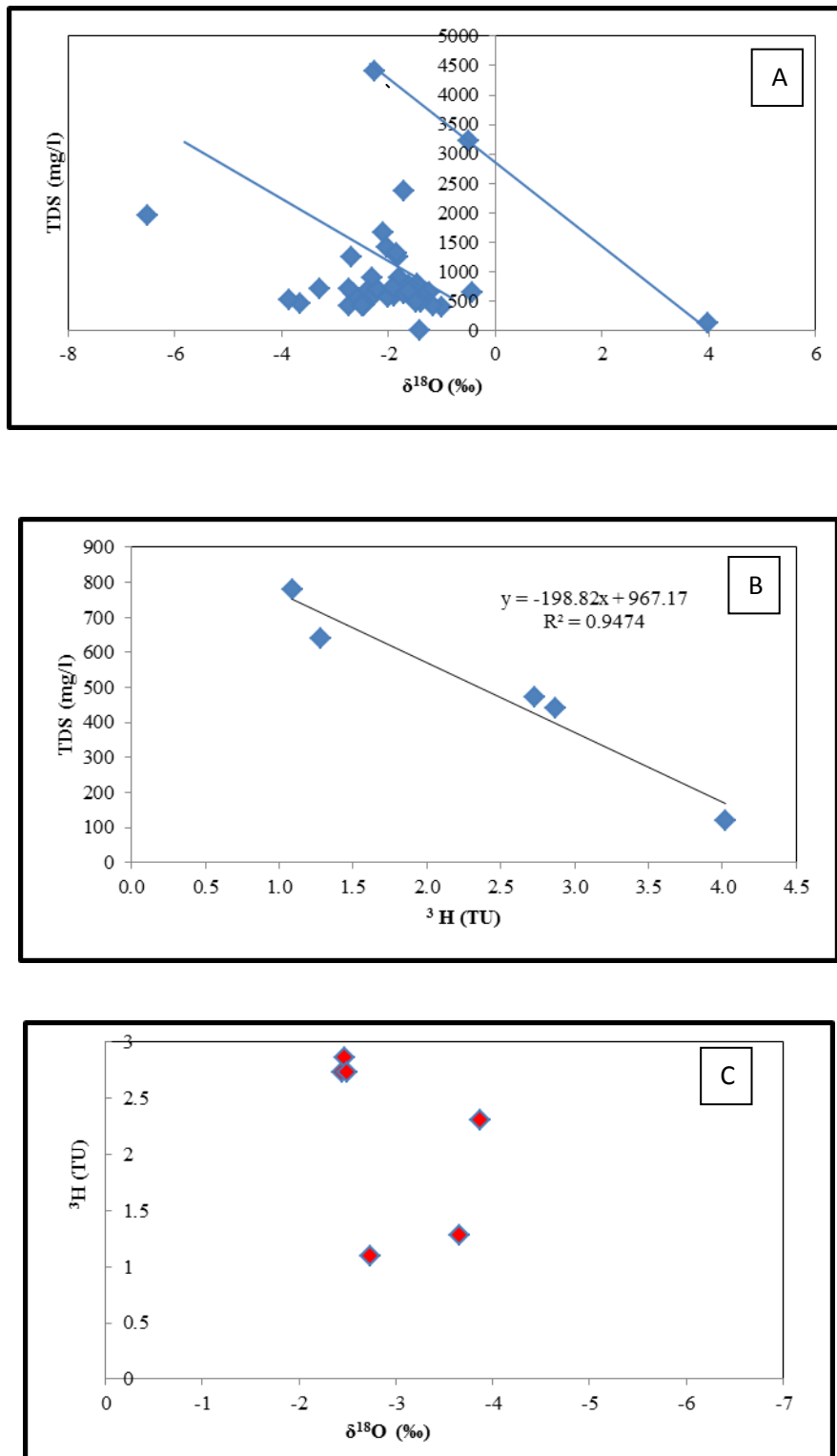
Fig. (5): A-The relation of TDS with $\delta^{18}O$ in the study area. B- Relation of TDS with Tritium in the studied samples. C- Relation of Tritium with $\delta^{18}O$.

The relationships of : ($\delta^{18}O$ vs D , $\delta^{18}O$ vs TDS and TU vs TDS , $\delta^{18}O$ vs TU, & Figs 3, 5A, 5B and 5C respectively) indicate that Eocene limestone aquifer gets mixed recharge from Nile water system and upward leaked Paleowater. The following isotopic mixing equation no. (1), has been used to calculate the contribution of Paleowater recharge to the groundwater under study, (percentage contribution from Nile water = (1- percentage contribution of old groundwater).

$$\frac{Q\ old}{Q\ Total} = \frac{(\delta 18O\ Total - \delta 18O\ New)}{((\delta 18O\ Old - \delta 18O\ New))} \ldots\ldots\ldots(1)$$

Where Q_{Old}/Q_{Total} is the contribution of Nubian aquifer water in the collected groundwater samples, $\delta^{18}O_{Total}$ is the content of $\delta^{18}O$ in the collected sample, $\delta^{18}O_{Old}$ is the value of the $\delta^{18}O$ content in the Nubian Sandstone and $\delta^{18}O_{New}$ is the value of the $\delta^{18}O$ content in the Nile water.

Based on the previous equation, the percentage of Nile water contribution in the samples of mixed recharge varies from 26.8 % to 73.5%. Only 8% of the samples receive less than 50% of recent Nile recharge. While the majority of the samples (about 54%) receive recent recharge ranges from 60% to 70% and 26% of the samples receive 50-60 % and 12% of the samples receive more than 70% recharge from Nile.

Radiocarbon ages have been determined for 6 samples in the study area, (statistical analysis presented in Table 2 C). The values range from 4735 ybp to 10100 ybp (average about 6000 ybp). These are classified into two groups, 1.st group is represented by 6 samples with age ranges from 4735 ybp to 5649 ybp) average of 5022 ybp (and 2.nd group is represented by one sample (that was collected from the aquifer at the extreme western reach of the study area) with age equals 10100 ybp.

The sample of the 2.nd group has Oxygen 18 content equal -10‰ which is typical isotopic fingerprint of Paleowater, this indicates that the pure Paleowater in the study area has an average age of about 10100 ybp. The four samples of the 1.st group have $\delta^{18}O$ between -2.6‰ and -4.2‰ ; average about -3‰ which is equivalent to about 50% mixing ratio between recent Nile water of +3‰ and Paleowater of -10‰. This mixing ratio agrees with that indicated by ^{14}C age of the pure Paleowater sample of the 2.nd group, equal 10100 ybp which is about double the average age of mixed water of 1.st group (avg. 5000 ybp).

The $\delta^{18}O$ vs ^{14}C age relation has been constructed, Fig. (6A), this includes the mixed samples of 1.st group and the pure Paleowater sample of 2.nd group, in addition to the Nile water ($\delta^{18}O$ + 3(‰) & age 0 ybp). The distribution of the points fits a linear relation of a strong correlation (R^2=0.96) and the water samples of 1.st group are clustered half a way between the Paleowater in the study area and present day Nile water.
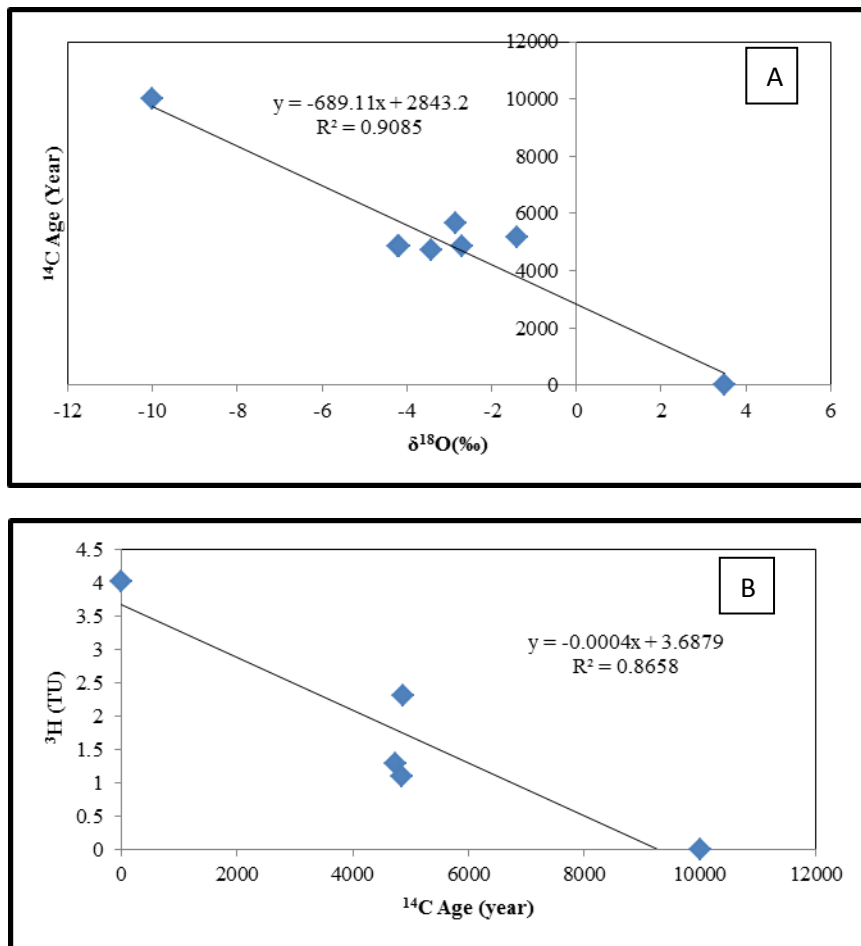

Figure (6): A- Relationship between $\delta^{18}O$ and ^{14}C age. B- Relationship between T (TU) and ^{14}C age.

The appearance of tritium in groundwater samples of thousands years age, Table (2C) assures mixing of recent recharge with Paleowater. The tritium content of the 1.st group varies in the range from 1.1 to 2.3 TU , average about 1.7 TU which is roughly equivalent to about 35% mixing between the recent Nile of 5 TU and the Paleowater of 0.0 TU. The difference between the mixing ratio (50%) roughly estimated based on $\delta^{18}O$ and that is based on Tritium (35%) may be related to the contribution of old Nile water reserved in the aquifer since before high dam and also due to the variant tritium input values. The relation of TU vs ^{14}C age, Fig. (6B) does not show the very strong correlation shown for $\delta^{18}O$ vs ^{14}C and the mixed water samples of 1.st group relatively dispersed around the trend line.

3.2. Usability of Groundwater in the Study Area
3.2.A. Evaluation of groundwater quality for drinking (Drinking Water Quality Index (DWQI)

The Canadian Environmental Quality Guidelines Index (Canadian Council of Ministry of the Environment (**CCME- WQI 2001**) has been used to evaluate the groundwater under study for drinking purposes. This index is based on a combination of three factors, Scope F1, frequency F2, and amplitude F3. Sixteen Hydrochemical parameters have been selected as (variables) from the analytical results of major ions and trace elements of the study groundwater samples. These have been compared with the corresponding (objectives) values in the **Egyptian High Committee of Water Guidelines for Drinking Water Purposes (2007)**

Table (3): Selected Objective based on the Egyptian High Committee of Water (2007)

Objective	Value	Objective	Value
pH	6.5-8.5	B(mg/l)	0.5
TDS(mg/l)	1000	Al (mg/l)	0.2
Hardness(mg/l)	500	Cr (mg/l)	0.05
Ca^{2+}(mg/l)	350	Cd(mg/l)	0.003
Mg^{2+}(mg/l)	150	Cu(mg/l)	2.0
Na^+(mg/l)	200	Mn(mg/l)	0.4
SO_4^{2-}(mg/l)	250	Ni(mg/l)	0.02
Cl^-(mg/l)	250	Pb(mg/l)	0.01
Mo (mg/l)	0.07	Zn(mg/l)	3.0
Fe(mg/l)	0.3		

After the variables and the objectives have been defined in Table (3), each of the three factors (F1, F2, and F3) that make up the CCME WQI index are calculated according to the method adopted by Canadian Environmental Quality Guidelines (2001). The definition of the different parameters used in the calculation of the index and the equations used are described in **CCME- WQI 2001** as follows:

F1 (Scope) represents the percentage of variables that do not meet their objectives at least once during the time period under consideration "failed variables", relative to the total number of variables measured:

F1= (Number of Failed Variables/Total Number of Variables) X 100

F2 (Frequency) represents the percentage of individual tests that do not meet objectives ("failed tests"):

F2= (Number of Failed Variables/Total Number of Variables) X 100

F3 (Amplitude) represents the amount by which failed test values do not meet their objectives. *F3* is calculated in three steps.

i) The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an "excursion" and is expressed as follows.

$$excursion_i = \{(\text{Failed Test Value}_i / \text{Objective}_j)\} - 1$$

ii) The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as the normalized sum of excursions, or *nse*, is calculated as:

$$nse = \sum_{i=1}^{n} excursion_i / no\ of\ Tests$$

iii) *F3* is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (*nse*) to yield a range between 0 and 100.

$$F3= \{nse/(0.01nse+0.01)\}$$

Once the F1, F2 and F3 factors have been determined, the overall water quality index CCMEWQI can be calculated by summing the three factors as if they were vectors according to the following equation:

$$CCMEWQI = 100 - \{\sqrt{(F_1^2 + F_2^2 + F_3^2)}\}/1.732$$

The calculated values of drinking water quality index of the study samples have been interpolated in ARCGIS 10.3 Tool as categorization of the overall calculated quality index for drinking purposes suitability, Fig.(7)**.** About 60% of the collected groundwater samples are categorized as poor (almost always threatened) and 40% are Marginal (frequently threatened) when used for human drinking according.
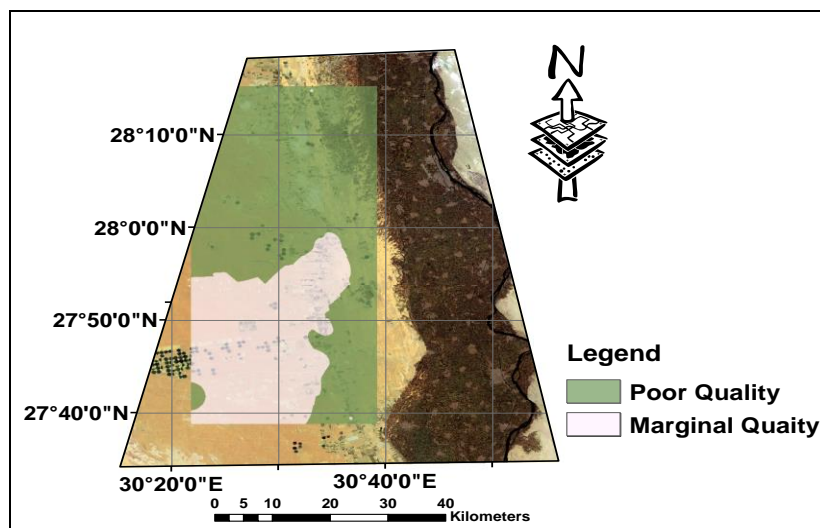
Fig.(7): WQI map of the study area

Based on the previous WQI for drinking water in the study area that revealed all groundwater are not suitable for drinking, further insight evaluation for the water samples for chronic daily intake in case of drinking have been evaluated in this paper as following.

3.2. B The human health risk assessment

Recently, the United States Environmental Protection Agency (USEPA) established a human health risk assessment (HHRA) model that is a widely used method to evaluate the potentially harmful effects of groundwater contaminants on the health of children and adults **(Adimalla and Wu 2019)**. Health risks due to contaminants in groundwater were calculated and the risks of oral water

$$\text{CDI ingestion} = C*IR* EF*ED /BW*AT$$

Where; CDI is the average daily dose of oral intake route, (mg (kg d)^{-1}) and C is the concentration of pollutants in groundwater (mg L^{-1}), which depends on laboratory analysis. EF is the Exposure frequency, ED is the Exposure duration, BW is the Average body weight, AT is the Average time (life time), the daily consumption of drinking groundwater corresponding to the exposure frequency was calculated as 2 L/day for adults, while average body weight was used is 70 kg for adults, **(Hagagg etal, 2020)**.

The HQ for each heavy metal was estimated using the ratio of computed mean daily intake (ADI, mg/kg/day) of a metal ingested with contaminated water to the reference oral dose (RfD) through oral ingestion and dermal absorption for the residents, the RfD values were suggested by (US EPA, 2005). The sum of all HQs gives an estimation of total potential health risks or HI. The calculation of the HI caused by water is presented below.

$$\text{HQ} = \text{CDI/ RfD}$$
$$\text{HI} = \sum_i^n \text{HQi}$$

Based on the above equation, values of CDI and HQ for every element, it was revealed that consuming these water has an adverse effects on the human health with respect to carcinogenic effect and non-carcinogenic effect, the calculated data have been interpolated using ARCGIS as geospatial analysis tool, a health risk assessment map have been estimated in Fig.(8), to demarcate the worst area of adverse effect on human health.
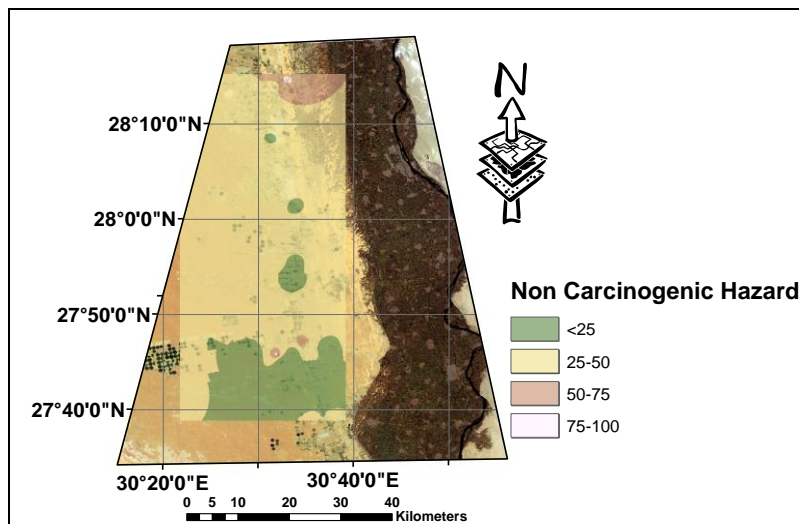
Fig.(8): Non-Carcinogenic health hazard of groundwater samples in the study area.

As discussed above, non-carcinogenic risks are high in study region for adults, Fig.(8) shows the interval values for non-carcinogenic risks of different ions in drinking water. In addition to that, it was revealed that both Cr and Pb increase the magnitude of non –carcinogenic hazard in the study area which motivate us to further assess the carcinogenic hazard of those elements, Fig.(9A and 9B). The extensive use of fertilizers in agricultural applications is typically the cause for the high concentration of trace elements in the study area.
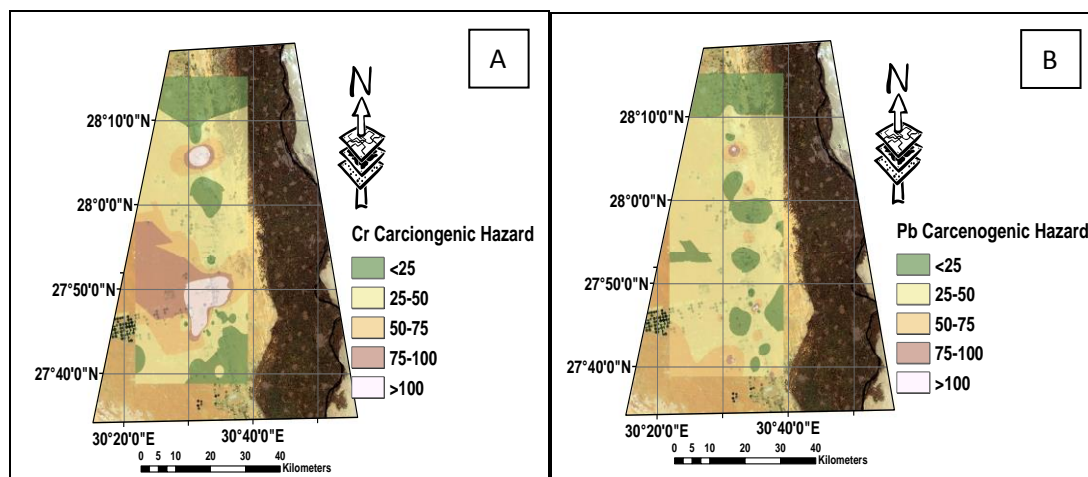

Fig.(9): A- Cr Carcinogenic health hazard of groundwater samples in the study area. B- Pb Carcinogenic health hazard of groundwater samples in the study area

IV. Conclusion
- The groundwater of the study area, southwest ElMinia is tapped from two aquifers: limestone that is related to Eocene age and sandstone that is related to Pleistocene.
- Major sources of recharge of the sampled groundwater wells of Eocene aquifer are Nile water and Paleowater that leaks upward from deep Nubian Sandstone aquifer.
- The recharge generally takes place as a lateral seepage from the interconnected Quaternary aquifer and Nile water system and vertically as upward leakage (through structural and fractural elements) from the deep seated Nubian sandstone Paleowater. No significant chance occurs for surface evaporation while recharge.
- About 60% of the collected groundwater samples are categorized as poor (almost always threatened) and 40% are Marginal (frequently threatened) when used for human drinking.
- Human health risk assessment of trace elements was found to be high and will affect on human health.

Compliance with ethical standards
Ethical approval and informed consent: Not applicable.
Consent for publication: Not applicable.
Conflict of interest: The authors declare that there are no competing interests.

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